Taxonomic revision of *Isoetes* L. in Western Australia

by E. R. L. Johnson*

(completed by Hj. Eichler** from notes left by Mrs. E. R. L. Johnson)

Manuscript received 22 February 1983; accepted 20 September 1983.

Abstract

A taxonomic revision of *Isoetes* L. in Western Australia is presented and eight species are described and illustrated. Six species are endemic of which *I. brevicula, I. caroli, I. inflata* and *I. mongerensis* are newly described and *I. australis* and *I. tripus* previously known. The remaining two species, *I. drummondii* and *I. muelleri,* are widespread in other Australian States.

Populations of young sterile plants of *I. australis* and homosporous ones of *I. australis, I. drummondii, I. mongerensis* and *I. muelleri* are reported. Dimorphic megaspores were found in populations of *I. drummondii, I. mongerensis* and *I. muelleri.*

Two keys are provided, one is based on vegetative characters and the other includes features of mature megaspores. Lectotypes are designated, where appropriate, for the names of other Australian *Isoetes* species not occurring in Western Australia.

Introduction

Isoetes L., one of the heterosporous Lycopsida, was first described from Western Australia in 1864 and 1868 by Alexander Braun. His specimens were collected by James Drummond in 1843 at the Swan River. Drummond's plants were probably included in a collection of cryptogams he sent to Sir William Jackson Hooker at Kew in August 1844 (Erickson 1969). Drummond numbered his *Isoetes* specimens 989 and 990, but no mention of these numbers has been found in a search of the letters he sent to Sir William about that time (Carrick, comm. 1970). In a later letter to Sir William (No. 140, 7 March, 1846) Drummond mentioned finding a third kind of *Isoetes* and commented on its habitat. This was similar to that in which some Western Australian species now occur. He wrote: "I found in shallow pools of rain water on granite rocks in the vicinity of the Wangan" (probably Wongan, auct.) "Hills a third species of this curious genus. It may be called *Isoetes minuata* . . . . Small as it is, it is produced in such numbers that it gives a green colour to the bottom of such pools. For 7 or 8 months in the year this little plant is exposed to the most extensive heat of the sun, where there is scarcely enough of dark coloured metallic sand to cover its minute roots. I have unfortunately mislaid the only specimens I collected of this curious little plant." No specimen or other record of this "third species" has since been found.

Drummond's specimens were incorporated in Hooker's and other herbaria, and duplicates are now at Berlin, Kew, Munich, Paris and Vienna. Braun (1864, 1868) described them as two new species, naming No. 989 *I. drummondii,* and No. 990 *I. tripus.* A number of their vegetative and reproductive features were described first in his paper on the Sardinian species of *Isoetes* (1864) and complete descriptions published later (1868). Since then *I. drummondii* is the only species recorded in all lists of Western Australian taxa.

Meanwhile in France Durieu (1864) published the results of his examination of specimens of *Isoetes* from the herbarium of the late Baron Delessert. Some of these had been collected by Drummond in "Nouvelle Hollande" in 1842 and 1843. The specimens were few and badly preserved, so Durieu, though he recognized three types of megaspores, would describe only one species which he named *I. phaeospora.* He characterized it by brownish megaspores covered with a network of deep sinuous meshes. Earlier in 1864 Braun had used these characters in describing *I. tripus* (Drummond's No. 990), so in 1868 he cited *I. phaeospora* Durieu as a synonym of *I. tripus.*

Figure 1.—General view of flat granite outcrop with rock pools west of Ballidu. *I. caroli* growing submerged. *Borya* sp. and *Cheilanthes* sp. fringing outer edge of a pool. Photo—K. F. Kenneally.

Bentham (1878) reduced the Western Australian species to one by including both *I. tripus* and *I. phaeospora* under *I. drummondii* as he considered they were not distinct because of their similar vegetative characters.

* Died 11 August 1972

** Australian National Herbarium, Division of Plant Industry, CSIRO, Canberra.

Mueller (1866) referred to *I. phaeospora* as occurring in the western extra-tropical parts of Australia, but omitted it from his Systematic Census (1882) and listed only *I. drummondii*. *I. tripus* was included in his Second Systematic Census (1889) and so restored to two the number of recorded species.

Baker (1880) in his Synopsis and Motelay & Vendryès (1882) in their monograph recorded *I. drummondii* and *I. tripus* for Western Australia and placed *I. phaeospora* as a synonym of *I. tripus*. Kuntze (1891) transferred both *I. drummondii* and *I. tripus* to the genus *Calamaria*, a pre-Linnean name for *Isoetes* which is not now recognized. Sadebeck (1902) placed both species in the genus *Isoetes* and so did Pfeiffer (1922) in her monograph, though she did not examine specimens of *I. tripus*.

Over the last hundred years little has been added to the results of Braun and Durieu. During this period, though many large collections of Western Australian plants have been made, few included specimens of *Isoetes*. Possibly collectors overlooked them because of their small size, sedgelike habit and absence of flowers.

Gardner (1930) in his Census of Western Australian Vascular Plants lists only *I. drummondii*, which is also the only species recorded by Blackall (1954). Willis (1953) who first recorded the *Isoetes* in the Recherche Archipelago as *I. drummondii* (form) emended this to *I. humilior* (1959). Smith (1966) also recorded *I. humilior* from Western Australia. Examination of the material has shown it to be *I. australis*, a species described by Williams (1943) from Western Australia. The publication of it was overlooked until recently, although it was listed by Reed (1953) in his Index.

The three species known to occur in Western Australia prior to the present study are *I. drummondii* A. Braun, *I. tripus* A. Braun and *I. australis* S. Williams.

Material and methods

In August 1958 the late Charles A. Gardner, then Government Botanist of Western Australia, gave to the author a large collection of *Isoetes* he had made near Lake Monger (now known as Mongers Lake). The exact site or sites of this collection is not known as Gardner in his field notes gave only "...near Lake Monger" as the location. This lake is situated between lat. 28°45'-29°56'S and long. 116°48'-117°19'E, its mid-point being about 246 km east-south-east of Geraldton. It is an irregular stretch of water with a long shore line very narrow in some parts and in others never more than 16 km wide.

From a preliminary examination of Gardner's collection and a report by Smith (1966) it was evident that in Western Australia there occurred a number of forms of *Isoetes* which could not be referred to any known species and a study of the genus in Western Australia has been carried out at the State Herbarium of South Australia. Additional material was made available on loan from AD, ADW, B, CHR, K, M, MEL, MO, NY, OXF, P, PERTH, SYD, US, UWA, W and WELT.

Figure 2.—Shallow pool on a granite outcrop south of Pithara. *I. inflata* growing wholly or partly submerged around its edges. Photo—K. F. Kenneally.

Figure 3.—*I. muelleri* growing submerged in rock pool, Glen Cuming Rawlinson Range. Photo—A. S. George.

The number of collections and sheets examined was 266 of which 189 were of *Isoetes* from 90 different localities in Western Australia and 6 were of small aquatic Angiosperms. The remainder were of *I. drummondii*, *I. muelleri* and other Australian taxa from localities in other parts of Australia.

As this journal is unable to publish long lists of specimens for each species, for the more common species only a selection of those examined is cited. Complete lists of collections examined are deposited at AD, CANB and PERTH. An asterisk denotes that only wet-preserved material (formalin or alcohol) was available. Maps show the distribution of each species in the South-Western and Eremean Provinces which are two of the three Climatic Provinces in Western Australia in relation to vegetation as delimited by Gardner (1942). Spore measurements give the approximate range of spore size. Megaspores were measured dry at × 10 and microspores in water at approximately × 400. Dimorphic

megaspores were counted when found in the same sporangium. Spore colour is that seen when dry megaspores and dry massed microspores are viewed against a white background in daylight or when wet with water.

Keys to the Western Australian species of Isoetes

The first key, based on vegetative characters, may be used to distinguish species at most stages of growth. The second key requires fertile plants with mature dry megaspores.

(a) *Key based on vegetative characters*

(1) Stock 2-lobed; leaves usually short, 4 cm or less.
  (2) Leaves ± terete above the wings, attenuate, sometimes falcate (Fig. 4) .... 1. *I. australis*
  (2) Leaves inflated above the wings, acuminate with apiculate apex often dark (Fig. 10) .... 5. *I. inflata*

(1) Stock 3-lobed; leaves short or long ca. 0.4-12 cm.
  (3) Leaves < 4 cm; wings short above ligule, ending towards middle of adaxial leaf surface.
    (4) Leaves < 1 cm (Fig. 6) .... 2. *I. brevicula*
    (4) Leaves > 1 cm.
      (5) Leaves ± divergent, firm, narrow, attenuate (Fig. 12) .... 6. *I. mongerensis*
      (5) Leaves ± upright, soft, terete, broadening about the middle then acuminate (Fig. 8) .... 3. *I. caroli*
  (3) Leaves > 4 cm, semiterete, attenuate; wings long above ligule, ± lateral, narrowing gradually.
    (6) Brown scale leaves present (Fig. 9) .... 4. *I. drummondii*
    (6) Brown scale leaves absent.
      (7) Stock small; leaves ± lax, velum present (Fig. 13) .... 7. *I. muelleri*
      (7) Stock prominent, firm, leaves slender, velum absent (Fig. 14) .... 8. *I. tripus*

(b) *Key including megaspore characters*

(1) Stock 2-lobed, mature megaspores ± black when dry.
  (2) Megaspores ± round, smooth or with faint tubercles (Fig. 4) .. .... 1. *I. australis*
  (2) Megaspores ± 3-lobed, tubercles small, on distal face often confined to three areas separated by furrows (Fig. 10) .. .... 5. *I. inflata*

(1) Stock 3-lobed; mature megaspores not black when dry.
  (3) Leaves usually < 1 cm long (Fig. 6) .. .. 2. *I. brevicula*
  (3) Leaves > 1 cm long.
    (4) Megaspores with numerous tubercles, crests few mostly short, few confluent.
      (5) Tubercles and crests crowded (Fig. 9) .. .... 4. *I. drummondii*
      (5) Tubercles and crests distant (Fig. 12) .... 6. *I. mongerensis*
    (4) Megaspores with few tubercles, crests numerous, many branched and confluent.
      (6) Crests ± close, often forming reticulations (Fig. 14) .... 8. *I. tripus*
      (6) Crests distant.
        (7) Crests on distal face ± rounded (Fig. 8) .... 3. *I. caroli*
        (7) Crests on distal face sharp (Fig. 13) .... 7. *I. muelleri*

1. **Isoetes australis** S. Williams, Proc. R. Soc. Edinburgh, Sect. B, 62 (1): 1-8, fig. 1 and 2, t. 1-3 (1943); Reed, Bol. Soc. Brot. II, 27: 15 (1953).—*Typus:* "collected in 1930 from rock pools in granite outcrops of Bruce Rock, 150 miles inland from Perth, Western Australia." *Lectotypus* (or *neotypus*): Western Australia. Bruce Rock: 1930; *F. R. Drummond and D. C. Swan s.n.* (PERTH lecto or neo (transferred from UWA), AD 97339092). (See note on lectotypification below.)—Figs. 4, 5. [*I. humilior* auct. non F. Muell. ex A. Braun (1853): Willis, Muelleria 1: 98 (1959); Smith, J. R. Soc. W. Austral. 49: 4 (1966).]

Plants small, 1-4 cm tall, rarely 5-9 cm; leaves few, distichous, bases closely overlapping on a laterally elongated stock, roots numerous, long. *Stock* bilobed with a shallow vertical groove between the lobes, leaf-bearing part pale, fleshy, extended laterally by dark desiccated, flattened segments, the remains of stocks of former seasons. *Leaves* 3-6, rarely 6-10, ca. 1-4(9) cm long × ca. 1-1.5 mm broad, ± terete, attenuate, sometimes falcate, without chlorophyll towards base; wings broad at base, closely overlapping, firm, short, distal ends truncate or rounded ending on the adaxial leaf surface ca. 2 mm above the sporangium; ligule reniform, margin crenate, on old leaves usually partly within the fovea concealed by the sporangium; labium very short; velum absent; fovea deep, edge

often acute projecting shortly over sporangium; stomata absent; peripheral strands absent. *Megasporangia* ± circular and flat in face view, 2-2.5 mm diam., deeply sunken in fovea, becoming dark as spores mature; wall firm, hyaline, vertical walls of epidermal cells slightly thickened, yellowish; megaspores usually few (4-12) per sporangium, rarely 24 or more, ca. 350-500 μm, immature dark greyish (wet), white (dry), mature black (wet and dry), sometimes with lighter areas, smooth or with faint low

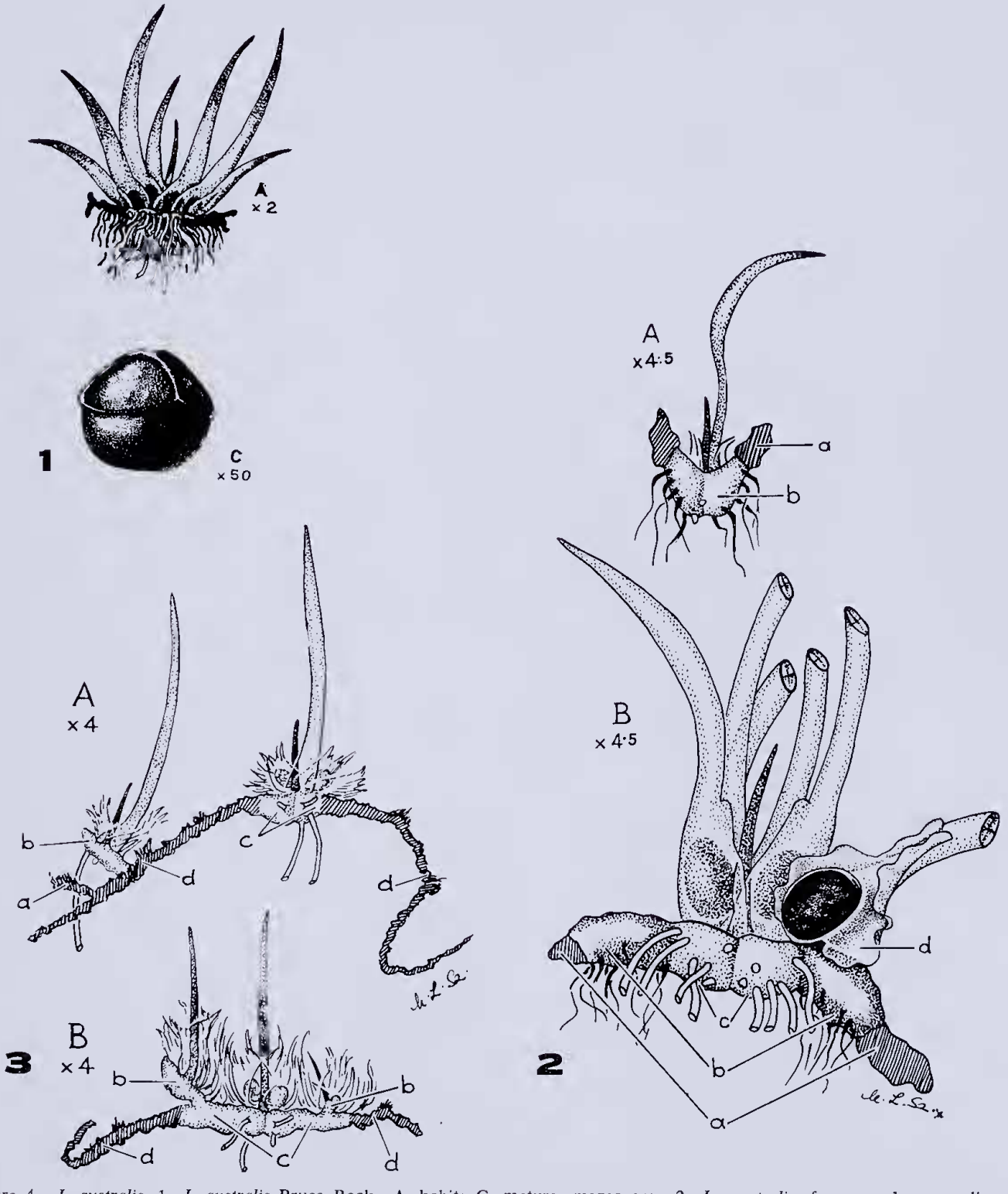

Figure 4.—*I. australis*. 1—*I. australis* Bruce Rock. A. habit; C. mature megaspore. 2—*I. australis* from pools on adjacent granite outcrops, One Mile Rocks, collected mid-November. A. Sterile plant, second growing season; *a* stock segments of previous season, *b* fleshy segments of current season. B. Fertile plant, third growing season; *a*, *b*, *c*, stock segments of three seasons; *d* outermost leaf showing microsporangium. 3—*I. australis*. Lateral stocks (old roots not shown). A. On stock of an earlier season, Stennet Rock. B. Onstock of current season, Albany Highway, 51 km south-east of Perth. *a* base of old branch, *b* young lateral stocks, *c* stock of current season, *d* lateral dessicated parts of stock segments of earlier seasons.

tubercles, commissural ridges prominent, rounded—brown; lateral view ca. 27-33 μm long × ca. 18-24 μm deep, wall thick, brown, spinulose, spines pointed or truncate, crests narrow when present, usually absent.

Distribution (Fig. 5): *I. australis* is widely distributed in Western Australia in the central and eastern part of the South-Western Province and in the adjacent south-western part of the Eremean Province acute, equatorial ridge thinner. *Microsporangia* similar in size, shape and structure to megasporangia; microspores in mass immature pale, mature dark below lat. 30°S. Further south it is found in the Eremean Province south of Norseman and in the South-Western Province between Lake King and Ravensthorpe, east of Esperance and on Middle Island, Recherche Archipelago.

Specimens examined (selection only): Western Australia: Nungarin Hill ca. 5 km north of Nungarin; 13.ix.1970; *N. Marchant 326* (PERTH*).—Yorkrakine Hill; 19.ix.1926; *C.A. Gardner* (UWA*).—24 km east of Jura Railway Siding on Merredin-Bruce Rock line; 1934; *E. T. Bailey* (OXF).—Albany Highway at 31 mile peg; 22.v.1964, 14.vi.1970; *G. G. Smith* (UWA).—Tuttanning Reserve south-east of Pingelly; 5.ix.1971; *A. S. George 10904* (PERTH).—Boyatup Hill, ca. 110 km east of Esperance; 1.x.1968; *A. E. Orchard* 1274 (AD).—High Island, Duke of Orleans Bay; 2.x.1968; *P. G. Wilson 8191* (PERTH).—Wittenoom Hills, ca. 50 km north-north-east of Esperance; 4.x.1968; *N. N. Donner 2893* (AD).—Middle Island, Recherche Archipelago; 22.xi.1950; *J. H. Willis* (MEL).

Observations: Small plants (Fig. 4.1) grow completely submerged in pools on granite outcrops, often so closely massed that they form a green underwater sward. Depth of water in the pools is from 3 to 10 cm, in a few cases 15 to 40 cm. The OXF sheet of E. T. Bailey's Bruce Rock collection of 1934 was annotated by Professor T. G. B. Osborn "—. habitat rock pools 2 sq. ft to ½ acre, water to 18" but plant rarely found below 6"." Only in a few of the collections cited was the depth of water in which the plants were growing stated, though the depth of the pools was noted. The average leaf length was about 2 cm. Longer leaves 4-9 cm long were on plants growing in a pool 30 cm deep on the top of Boyatup Hill and they were 3-7 cm on plants from Middle Island, but no depth of water was recorded. Pools with shallow water gradually dry out in the late spring and by December or earlier are completely dry. During this time the leaves die down and stocks with leaf bases and sporangia become desiccated and mixed with the detritus left on the rock surface. During the summer, this is exposed to periods of extreme aridity and high insolation, and the occasional summer rains, if any occur, provide only temporary water in the depressions. Regrowth of the stock does not take place during such short wet periods but recommences after the pools become permanent following the beginning of the next winter rains about April or May. In the laboratory growth from dry stocks as well as sporelings appeared after about four week's immersion in rain water.

Table 1

I. australis—Homospory and Heterospory in collections of young plants.

Locality	Date Collected	Sterile	Fertile	Homosporous		Hetero-sporous	Mega-spor-angia small	Aborted spor-angia	Loose spores and sporelings	Notes
				microsp.	megasp.					
Albany Highway 40 mile peg	July, 1963	....	0	....	0	....	....	....	few	microsporangia may have developed later in season
Mt. Hampton	Sept., 1964	0	0	....	....	0	....	....	numerous	fertile plants in third growing season
Jilakin Rock	Aug., 1970	....	0	....	....	0	....	....	....	plants all young
Durgacutting Rock	Sept., 1970	0	0	0	....	0	0	0	few	microsporangia large
Mt. Stevens	Sept., 1970	0	0	0	....	....	....	0	few	fertile plants few, sterile in first growing season
Mt. Madden (498)	Sept., 1970	0	0	0	....	few	rare	....	....	plants in drying pool, most in first growing season
Mt. Madden (499)	Sept., 1970	0	0	0	....	few	rare	....	numerous	plants in a deep pool, of different ages
One Mile Rocks (10489)	Nov., 1970	0	....	....	....	....	....	....	a few spores	plants in drying pool, near end of second growing season
One Mile Rocks (10491)	Nov., 1970	....	0	0	....	few	rare	....	numerous megaspores	plants all fertile, some old ones present
Bald Rock	Sept., 1971	0	0	0	....	few	rare	....	....	a few older plants present

Table 2

I australis—Distribution of sporangia in a population of young plants from Durgacutting Rock. Numbers of plants in brackets ( ).

Sporangia	No. of plants	Sporangia per plant		Aborted	Megaspores per sporangia μm
		micro-	mega-		
Microsporangia only	36	1 (4) 2 (16) 3 (12) 4 (4)	....		
Microsporangia and small megasporangia	15	1 (6) 2 (7) 3 (2)	1 (13) 2 (2)	....	4 (4) 8 (7) 12 (3) 16 (1) 16 (2)
Microsporangia and aborted sporangia	11	1 (1) 2 (6) 3 (2) 4 (2)	....	1 (8) 2 (3)	
Total	62	141 (62)	17 (5)	14 (11)	

Two periods of growth in the season 1971 were shown by plants from Newcarlbeon Soak and Stennet Rock. On the distal parts of the stocks were the remains of leaves, mature sporangia and shrivelled roots, and in the central parts developing leaves and roots, (Fig. 4.3), the former had the appearance of plants at the end of a growing season and the latter like those at the beginning of one. Field notes stated that at Newcarlbeon Soak the "pool had apparently dried out during the spring and refilled after recent rains" and at Stennet Rock in mid-November "water in the pool was 3.5 cm deep." Rainfall statistics show that dry periods occurred in both localities earlier in that season and in late spring rainfall was more frequent and heavier. These observations suggest that in shallow pools a falling water level may be one of the factors involved in spore maturation and cessation of growth towards the end of a growing season. In both cases active growth was resumed without the usual summer period of rest and exposure to high temperatures and aridity. Burbank and Platt (1964) have reported the same type of cessation and renewal of growth in *I. melanospora* from Georgia when growing under similar environmental conditions.

Spore production was observed to commence in one plant's third growing season. The younger sterile plants (Fig. 4.3A) were small with few leaves and fleshy swollen stocks often with slightly shrunken segments of the previous season attached to their distal ends. Young fertile plants (Fig. 4.3B) had 4 to 6 leaves and 1 to 4 large microsporangia. The outer leaves, if present, were sterile or bore one, rarely two, small megasporangia with few small spores, or aborted sporangia.

Larger megasporangia with microsporaniga typical of older heterosporous plants were found in only two populations of young plants from Jilakin Rock and Mt. Hampton. Details of the different types of spores in a number of young populations are given in Tables 1 and 2. These indicate that heterospory is variable in young fertile plants and that they tend to be wholly or potentially homosporous (microsporangiate).

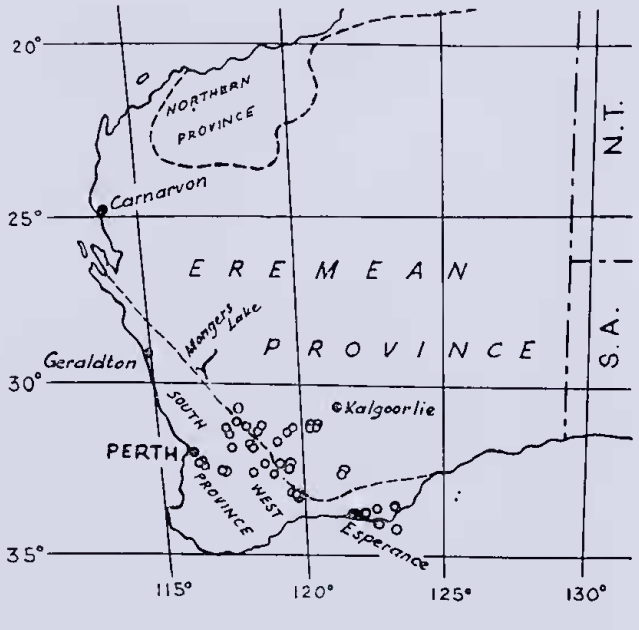

Figure 5.—Distribution of *I. australis*, O.

On a number of plants were small lateral fleshy stocks associated with the axils of the leaves (Fig. 4.2). The smallest one seen was a small fleshy outgrowth from the upper surface of the main stock, with a rounded distal end, a single small leaf near the mid-point of its abaxial surface and no roots. Larger stocks had two longer leaves and young roots. These differ in position and development from the small apogamous leafy shoots, on which stocks and roots develop later, which replace the sporangia in *I. lacustris* and *I. echinospora* (Goebel 1879). The structures in *I. australis* appear to be small axillary branches on which leaves and then roots develop. Pfeiffer (1922) refers to the branching of "the corm" being rare, but does not cite any examples. In *I. australis* the young lateral stocks were frequent in two collections and would be a means of vegetative reproduction.

A submerged species common in rock pools on granite, characterized by its bilobed stock bearing few, often falcate, leaves and mature megaspores which are smooth or faintly tuberculate, black or dark greyish-black.

Note on lectotypification: Dr Samuel Williams did not designate a type specimen when he published the description of *I. australis* in 1943. He saw specimens collected at Bruce Rock in 1930 and sent to Professor J. Walton at Glasgow in 1934 by Miss Alison Baird of Perth, and from Professor T. G. B. Osborn air dried plants, grown in his laboratory at Sydney, and collected by E. T. Bailey in 1934 near Bruce Rock, and herbarium specimens also collected at Bruce Rock by Bailey. The specimens on which Williams based his description, for which a search was made at Glasgow and Edinburgh (E), have not been found. Williams stated that his "description is mainly based on Miss Baird's material". According to information from Miss Baird, this was collected in 1930 at Bruce Rock by F. R. Drummond and D. C. Swan, and at least part of it is still held in the Botany Department of the University of Western Australia. A sheet in Oxford (OXF) bearing a series of plants annotated by Osborn as "coll. E. T. Bailey" without date at "15 m E of Jura Railway Siding on Merredin-Bruce Rock line, W.A." is noted as part of the original sheet sent to the British Museum (BM). A photograph of a small collection at BM shows that it was also made in 1934. There is no evidence that Williams saw either the OXF sheet or the BM specimens. I have examined from UWA a collection made in August 1930 at Bruce Rock by F. R. Drummond and D. C. Swan which represents part of the collection of which Miss Baird sent at least a portion in 1934 to Glasgow. Although it is uncertain whether Williams actually saw the part I examined (it may have been retained at UWA or returned by Williams after examination), I designate this portion of the syntype collection on which Williams mainly based the description of *I. australis* as the lectotype of this name. However, for purists who request the lectotype to be chosen from among elements that were definitely studied by the author (I.C.B.N. 1978, p. 75, Guide to the Determination of Types: 4, a) and who may claim that Williams possibly did not see UWA material I examined, and that for the same reason none of the existing specimens (OXF, BM, and UWA) qualify as lectotypes (all syntypes being lost), I designate the UWA material alternatively as neotype of *I. australis*. The type material has now been transferred to PERTH; AD received a portion of this collection from UWA which accordingly is an isolectotype or isoneotype.

2. **Isoetes brevicula** E. R. L. Johnson, sp. nov.—Figs 6 and 7. Caudex trilobus. Folia 4-8 mm longa, 1-1.5 mm diametro. Megasporae (immaturae?) leaves vel modice sulptae.—*Typus*: Western Australia. Graham Rock, 17.6 km east of Hyden, in shallow pools on granite, water 3-6 cm deep; 21.ix.1971; *N. Marchant 71/622* (PERTH holo, AD).

Plants (Fig. 6) very short to 1 cm tall with tuft of spirally arranged dilated shortly pointed leaves on a well-developed stock. *Stock* dark, prominent, 3-lobed, fleshy, 2-4.5 mm wide × 1-3 mm deep, abscission caps present. *Leaves* 4-8, 4-8 mm long × 1-1.5 mm diam. near mid-point of blade, fleshy, inflated ± terete flattened adaxially distally, apex acute often dark; wings short ca. 2.5 mm long, fleshy, at base 2.5-3.5 mm wide, narrowing above region of ligule, ending near middle of adaxial leaf surface; ligule on young leaves triangular, cordate at base, ± reniform on older ones; labium short, broadly triangular; velum absent, stomata absent; peripheral strands absent. *Megasporangia* immature, circular ca. 1.2 mm diam., adaxial surface flat; wall hyaline, slightly brown; megaspores 4-16 per sporangium, ca. 300-400 μm, pale to dark brown (wet), greyish-white (dry); proximal faces sculpturing absent or faint, tubercles low, variable in number, size and shape; distal face few small low crests and tubercles; commissural ridges prominent ± rounded; equatorial ridge thinner. *Microsporangia* similar to megasporangia, sometimes ± oval; microspores light brown, in lateral view ± 27-30 μm × 18 μm without crest, wall thick, crests present or absent.

Distribution (Fig. 7): *I. brevicula* is known only from Graham Rock (32° 28′ S 119° 02′ E) in the Eremean Province near its south-western boundary with the South West Province.

Observations: A collection of 15 plants growing submerged in a shallow rock pool on granite. All were heterosporous, with immature spores, except one which was sterile. This appeared to be in its second growing-season and had a well-developed fleshy stock bearing five leaves and three very small dark abscission caps.

Plants are distinguished from those of other species with 3-lobed stock by their small size, inflated leaves and smooth or faintly sculptured megaspores. It differs from *I. inflata* in its habit and 3-lobed stock.

3. **Isoetes caroli** E. R. L. Johnson, sp. nov.—Figs 1, 7 and 8. Caudex trilobus. Folia teretia, 2-4 cm longa, acuminata, lenia, plus minusve erecta, ad medium incrassata. Megasporae tuberculis paucis, cristis numerosis distantibus in superficie distali plus minusve rotundatis.—*Typus:* Western Australia. Near Lake Monger (now Mongers Lake), in granite rock pool; August 1958; *C. A. Gardner s.n.* (AD 97134006 holo, AD, PERTH.)

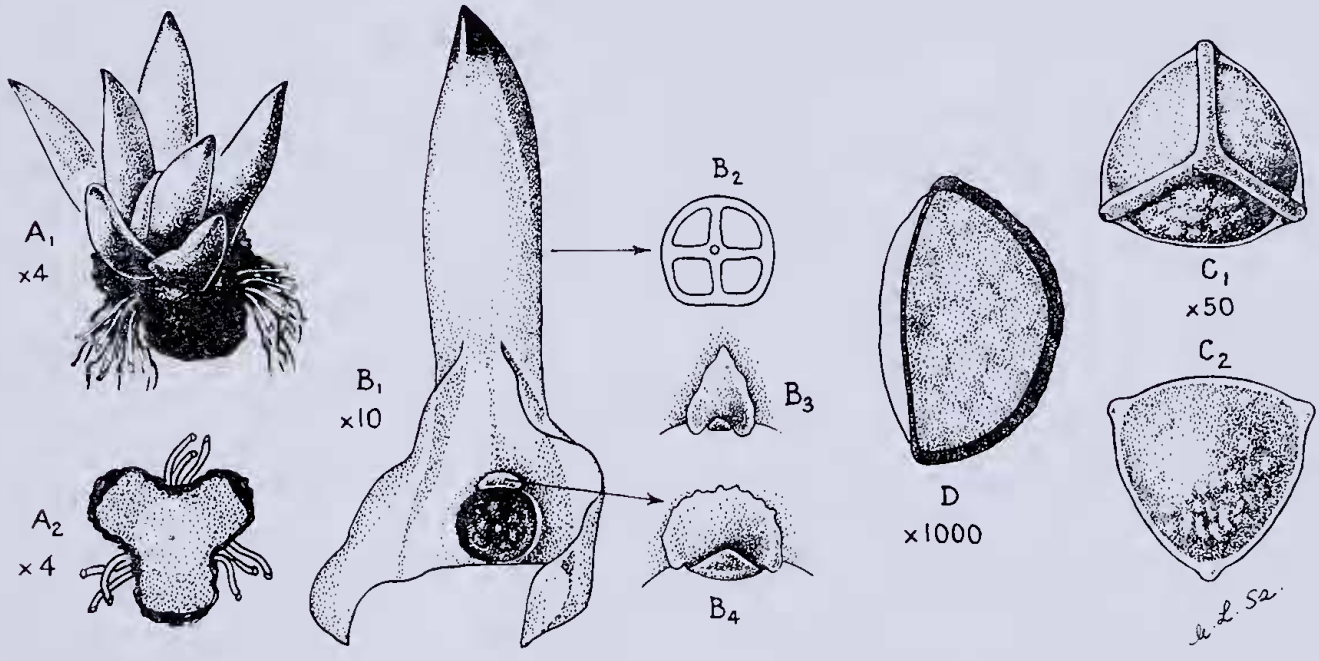

Figure 6.—*I. brevicula*, Graham Rock. A_1 habit, A_2 T.S. stock; B_1 megasporophyll, B_2 T.S. blade, B_3 ligule and labium on young leaf, B_4 ligule on mature leaf; C_1C_2 megaspore proximal and distal faces; D microspore, lateral view, optical section.

Plants (fig. 8A) small, (1)2-4(5) cm tall with a tuft of spirally arranged leaves on a well developed stock. *Stock* brown, 3-lobed, firm ca. 5 mm wide, abscission caps present, sometimes indistinct. *Leaves* (4)10-15(20), (1)2-4(5) cm long × 1-2 mm diam. in the lower and middle part, soft, terete, erect, sometimes ± falcate, tapering into the acuminate apex, with chlorophyll in the upper half or third of its length; wings thin, firm and fleshy, ca.(4)5-6(8) mm across at the base, narrowing gradually onto the adaxial leaf surface to about 8 mm above the ligule; ligule short, 0.25 mm long, reniform; labium small; velum absent; fovea deep with acute edges; stomata absent or sparse in upper part; peripheral strands absent. *Megasporangia* ± circular to broad-ovate, 2-3×1.8-2 mm, adaxial surface flat; wall brownish, firm, thickened; margins rounded; megaspores 8-36 per sporangium, 350-400 μm, dark grey (wet), greyish-white (dry); proximal faces with few low and faint markings; distal face with numerous mostly low tubercles and some branching and anastomosing crests; commissural ridges prominent, broad, rounded; equatorial ridge thinner. *Microsporangia* ± ovate 3.5×2 mm, dark, adaxial surface flat, silghtly margined, wall firm, opaque; microspores dark brown (wet), 15-18×30-53 μm, some crested, walls most by smooth or slightly crenulated and shortly and finely spinulose.

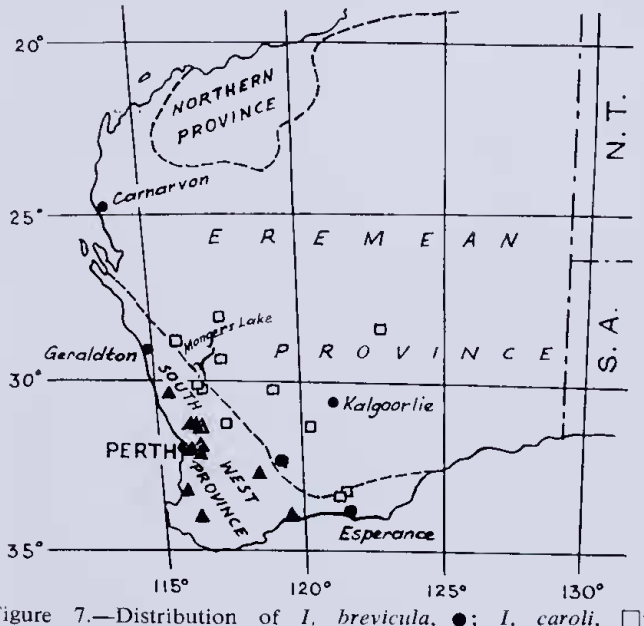

Figure 7.—Distribution of *I. brevicula*, ●; *I. caroli*, □; *I. drummondii*, .

Distribution (Fig. 7): *I. caroli* is widespread in the South-West Province of Western Australia where it is restricted to seasonal granite rockpools.

Specimens examined (selection only): Western Australia: 3 miles east of Wubin on Payne's Find Road; viii. 1964; *G. G. Smith* (AD, UWA379).—7.5 miles west of Ballidu on Bindi-Bindi—Ballidu road; 26.ix.1971; *K. F. Kenneally* (AD, UWA). Granite flats just southeast of Ballidu, in or close to shallow pools; 4.v.1960; *A. S. George 838* (PERTH). Yerritup Creek ca. 75 km west of Esperance; 27.ix.1968; *Hj.Eichler 20005* (AD).

Note: The epithet 'caroli' (from Latin *Carolus* = Charles) refers to Charles Austin Gardner (1896-1970), the collector of the type.

4. Isoetes drummondii A. Braun, Monatsber. K. Akad. Wiss. Berlin 7 Dec 1863:573, 593-595 (1864); 13 Aug 1868:528-530, 534, 542-544 (1868); Bentham, Fl. Austral. 7:672 (1878); Baker, J. Bot. 18:65, 70 (1880); F. Muell., Syst. Census Austral. Pl. 1:136 (1882); Mot. & Vendr., Actes Soc. Linn. Bordeaux 36:379, t. 13:4, 5 (1882); F. Muell., Sec. Syst. Cens. 1:228 (1889); Sadeb. in Engler & Prantl, Nat. Pflanzenfam. 1/4:777 (1902); Osborn, Trans. R. Soc. S. Austral. 42:1, 5, 10, fig. 3 (1918); Pfeiffer, Ann. Missouri Bot. Gard. 9:125, t. 15:15

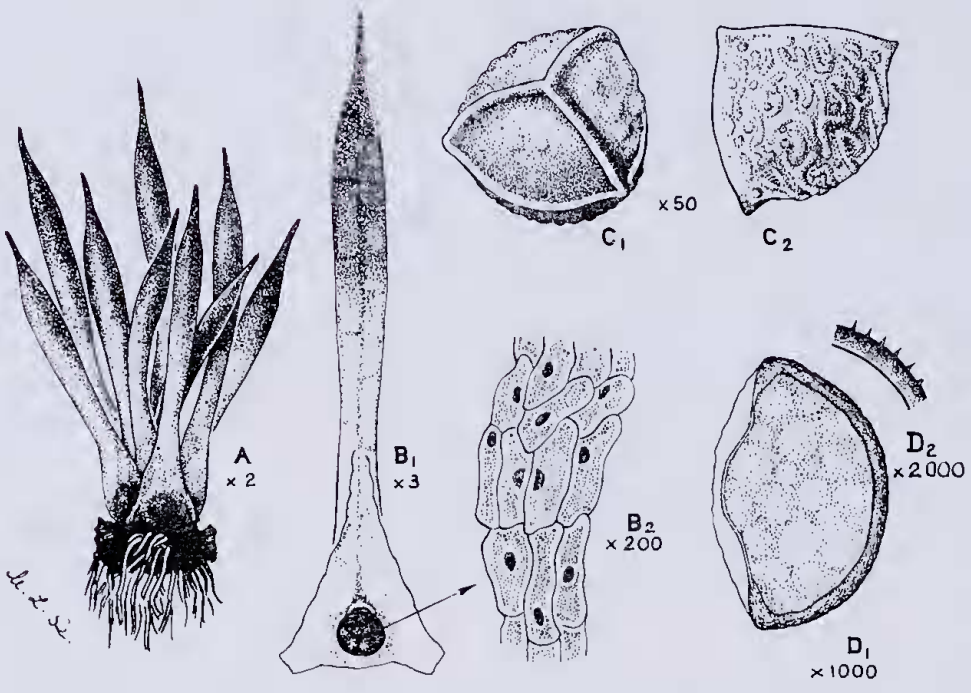

Figure 8.—*I. caroli*, Lake Monger. A habit; B_1 megasporophyll, B_2 sporangial wall hyaline cells; C_1C_2 megaspores proximal and distal faces; D_1 microspore, D_2 wall of older microspore (Wubin collection).

(1922); Osborn, Ann. Bot. 36: 41-54, fig. 1-15 (1922); Wiliamson, Vict. Nat. 44:228, fig. F (1927); Gardner, Enum. Pl. Austral. Occid.: 3 (1930); Reed, Bol. Soc. Brot. II, 27:20 (1953); Blackall, How to know W. Austral. Wildflowers 1:4 (1954); Wakefield, Ferns Vict. Tasm.: 65, fig. F (1955); Willis, Handb. Pl. Vict. 1:53 (1962); Smith, J. R. Soc. W. Austral. 49(1):4 (1966).—*Calamaria drummondii* (A. Br.) Kuntze, Revis. Gen. Pl. 2:828 (1891).—*Typus*: "... in herb. Vindob. et Hook. 1863 ... Ad flumen Swan River Novae Hollandiae australi-occidentalis l. *Drummond 1843 (no. 989).*" (W lecto, AD photo; K, P (mixed with *I. tripus*), W (the only sheet bearing Drummond's number label)). (See note on lectotypification below).—Figs. 7 and 9.

Plants (Fig. 9A) 4-10 cm tall with firm spreading leaves closely overlapping at the slightly bulbous base. *Stock* ± 1 cm broad × 2-5 mm deep, dark, 3-lobed, each lobe with a prominent persistent abscission cap. *Leaves* 9-10(18), 6-10 cm long × 1-1.5 mm broad near mid-point of blade, firm, semiterete, attenuate, green almost to the base; wings 6-10 mm broad at base, gradually narrowing above the level of the ligule, ± lateral; ligule triangular, cordate at base to 4 mm long × 2 mm across base, often shorter or damaged; labium short, firm, broadly triangular; velum absent; stomata present, sometimes sparse; peripheral strands absent; scale leaves small, hard, dark brown, shiny, acute, 2-3 mm long × 1-2.5 mm broad at base; mucilage cells in basal tissue of mature leaves; heavily thickened cells from dark brown area behind fovea. *Megasporangia* circular, oval or obovate, ca. 3-6 mm long × ca. 2-3.5 mm broad, adaxial surface flat, margined when mature; wall firm, immature pale, mature dark brown, epidermal cells thick walled, outer walls brown, inner very thick almost colourless, lumina narrow; megaspores ca. 300-400 μm, few ca. 500 μm, mature dry greyish-white; proximal faces covered with numerous small low tubercles, crests few, short; distal face crests numerous few-branched or confluent, tubercles fewer; commissural ridges low, rounded; equatorial ridge thin, acute. Dimorphic megaspores occasional in same sporangium, size difference ca. 150-200 μm. *Microsporangia* similar to megasporangia in size, shape and structure; microspores immature pale in mass, mature dark greyish-brown, densely spinose, in lateral view ca. 30-33 μm long × ca. 18-24 μm deep, not crested.

Distribution (Fig. 7): A species occurring in Western Australia mainly in the western part of the South West Province below lat. 30°S. A single collection was made by Diels in 1901 about 64 km west of Esperance near the Hamersley River between Ravensthorpe and Jerramungup. No other collection has been made from or near this locality. The site "Ad flumen Swan River" of Drummond's type collection is not known. Recent collections at Cannington and Toodyay, both near the Swan River, are about 80 km apart. *I. drummondii* is also known from the southern and south-eastern parts of Australia.

Specimens examined (selection only): Western Australia: Cannington Swamp; 22.viii.1947; *C. M. Eardley* (ADW).—Brookton-Armadale Road ca. 83 km from Perth; 10.xi.1960; *G. G. Smith* (UWA 483).—Tuttanning Reserve southeast of Pingelly; 5.ix.1971; *A. S. George 10908* (PERTH).—Harvey; 26.ix.1950; *R. D. Royce 3343* (PERTH).—South West Highway 20 km south of Bridgetown; 23.x.1962; *W. A. Loneragan* (PERTH, UWA 723).—Kent, östlich von Hamersley River; 12.x.1901; *L. Diels* 4906 (B).

Observations: Plants are semi-aquatic and grow in swampy sandy or clayey loam subject to seasonal flooding and extreme dryness in summer. Complete submergence is rare but the stock and lower parts of the leaves may grow in 2-5 cm of water. A series of collections of plants from Cannington showed that Braun's (loc. cit.) description of the sporangium as "... immarginatum (margine rotundum), pallidum, sclerenchymate carens" was of an immature one as it appears about half-way through the growing season. When mature at the end of the season (November-December) it is margined, dark brown, with heavily thickened epidermal cells. Also present are a thickened dark brown area in the leaf base

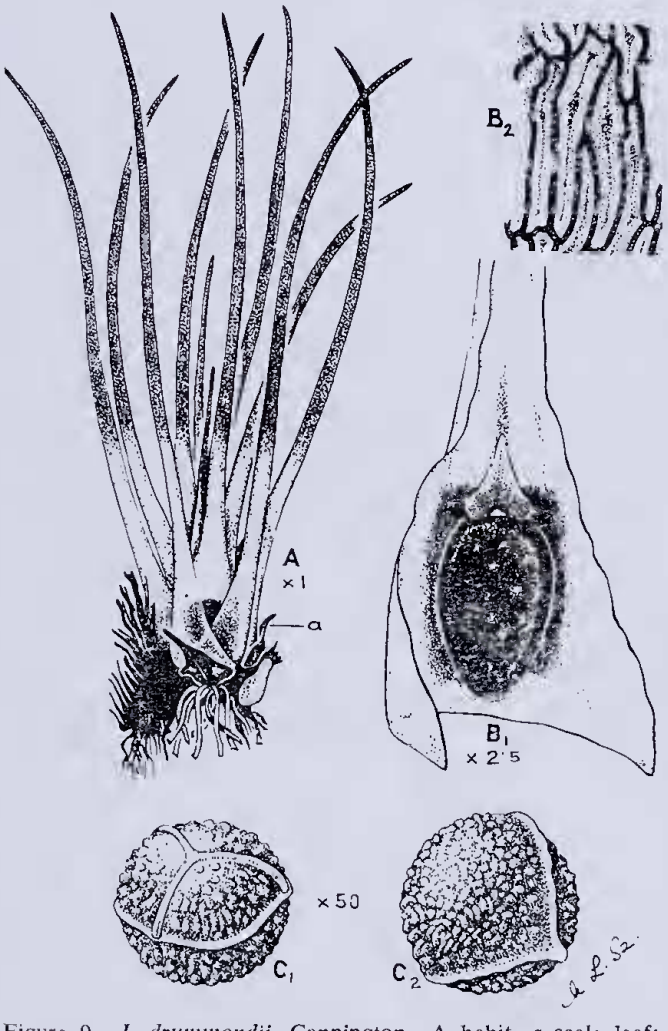

Figure 9.—*I. drummondii*, Cannington. A habit, *a* scale leaf; B_1 micro-sporophyll, mature microsporangium with thick wall and margin, dorsal area of sporophyll thickened, B_2 thick walled epidermal cells of sporangial wall; C_1C_2 megaspore proximal and distal faces.

behind the fovea, internal mucilage tissue and dark scale leaves around the growing apex. Osborn (1922) described similar structural changes in *I. drummondii* from South Australia and showed that the mucilage tissue functioned in spore dispersal at the beginning of the next wet season. Spore dispersal has not yet been observed in Western Australian plants.

In most collections plants were heterosporous. Homosporous ones with large mature and immature microsporangia were collected at Harvey at the end of September and only megasporangia, without any developing microsporangia, were on plants collected at Scrivener's Soak and Hamersley River late in the growing season.

Dimorphic spores occurred on plants from York Road (UWA 721) and south of Bridgetown. On plants from Scrivener's Soak were some abnormal megaspores, in polar view up to 500 μm long, oval in shape and with more than three proximal faces and commissural ridges. Braun (1868) noted two sizes of megaspores and the abnormal appearance of others in the Swan River plants.

A specimen from Toodyay (NY) recorded by Pfeiffer (1922) as *I. drummondii* "... coll. O.W.F" is emended to *I. tripus* coll. Oldfield. Its habit and megaspores are characteristics of *I. tripus* and O.W.F. was an incorrect interpretation of the pencilled abbreviation of Oldfield's name on the label.

On a P sheet were two specimens under Drummond's No. 989 referred to *I. drummondii*. Both, somewhat similar in habit, were immature. The left-hand specimen showed features characteristic of *I. drummondii* and the right-hand one those of *I. tripus*. Possibly before being mounted Drummond's number label (990) for *I. tripus* was lost or the specimens had become mixed.

Plants of this semi-aquatic species are distinguished by a few small brown scale leaves outside a tuft of firm tapering green leaves, the lower parts of mature sporophylls thickened and brown with internal mucilage cells and brown margined sporangia.

Note on lectotypification: In the first valid publication (1864) of the name *Isoetes drummondii* A. Braun does not give any indication of a type. In the second paper (1868) he lists "Ad flumen Swan River Novae Hollandiae australi-occidentalis 1. Drummond 1843 (no. 989)" and gives the location "herb. Windob. et Hook." (= W and K). I have seen both specimens and designate the W sheet as the lectotype and the collection at K as isolectotype. Both collections are annotated by A. Braun and of equal quality. The W sheet bears only *I. drummondii* (Drummond 989) whereas on the K sheet is mounted also a collection of *I. tripus*. On a B sheet in a packet annotated by A. Braun "Isoetes tripus mihi" were two small packets labelled by A. Braun "I. drummondii". One of these was empty and the other contained part of a leaf which was insufficient to verify the species. Other isolectotypes, not annotated by Braun, were seen from P and W.

5. **Isoetes inflata** E. R. L. Johnson, sp. nov.—Figs 2, 10 and 11. Caudex bilobus. Folia 0.5-1(2) cm longa, supra alas inflata, acuminata, apex apiculatus, saepe atratus. Megasporae plus minusve trilobatae; tubercula parva in superficie distali plerumque ad tres areas ab sulcis separatas limitata. —*Typus:* Western Australia. Near Lake Monger [now Mongers Lake], in mud of granite rock pool; August 1958; *C. A. Gardner s.n.* (AD 9713004 holo, AD, PERTH).

Plants (Fig. 11aA) small, 1-2 cm tall, partly or wholly submerged. *Stock* flat, 2-4 mm wide, 0.5 mm deep, two-lobed with shallow central vertical groove and persistent lateral strap-shaped 1-6 cm long extensions of previous years stock with brown leaf scars and long roots. *Leaves* (4)5-9(15) in

opposite rows, stout, almost terete, 0.5-2 cm long × 1-2.5 mm diam. at the widest point near the middle, tapering rather abruptly into a short, dark, bluntish tip, whitish opaque in lower part, green in upper 2/3-3/4 of length above the wings; wings short, fleshy membranous attached at the broad base to the stock for most of the width, overlapping the next younger ones so as to enclose the sporangium, narrowing above and gradually tapering and ending on adaxial surface to 2-3 mm above the fovea, or with an almost truncate end; edge of fovea acute, slightly extended as a rim around the sporangium; ligule thin, reniform, very short, 0.3-0.5 mm long × 2 mm broad; labium firm, short, rounded or pointed; velum, stomata and peripheral strands absent. *Megasporangia* oval to almost circular, 1.5-2 mm diam., adaxial surface flat; wall firm, thin, hyaline, sometimes with groups of brown cells in the inner layer; megaspores white, grey or black, ± three-lobed, 300-500 μm diam.; tubercles small, rounded, those on distal face often confined to three raised areas which are separated by furrows, those on proximal faces scattered; commissural ridges prominent, ± rounded; equatorial ridge thinner. *Microsporangia* similar to megasporangia, oval, 2 × 1.5 mm. Microspores dark brown, 30-36 × 18-24(28) μm, spinulose, crested.

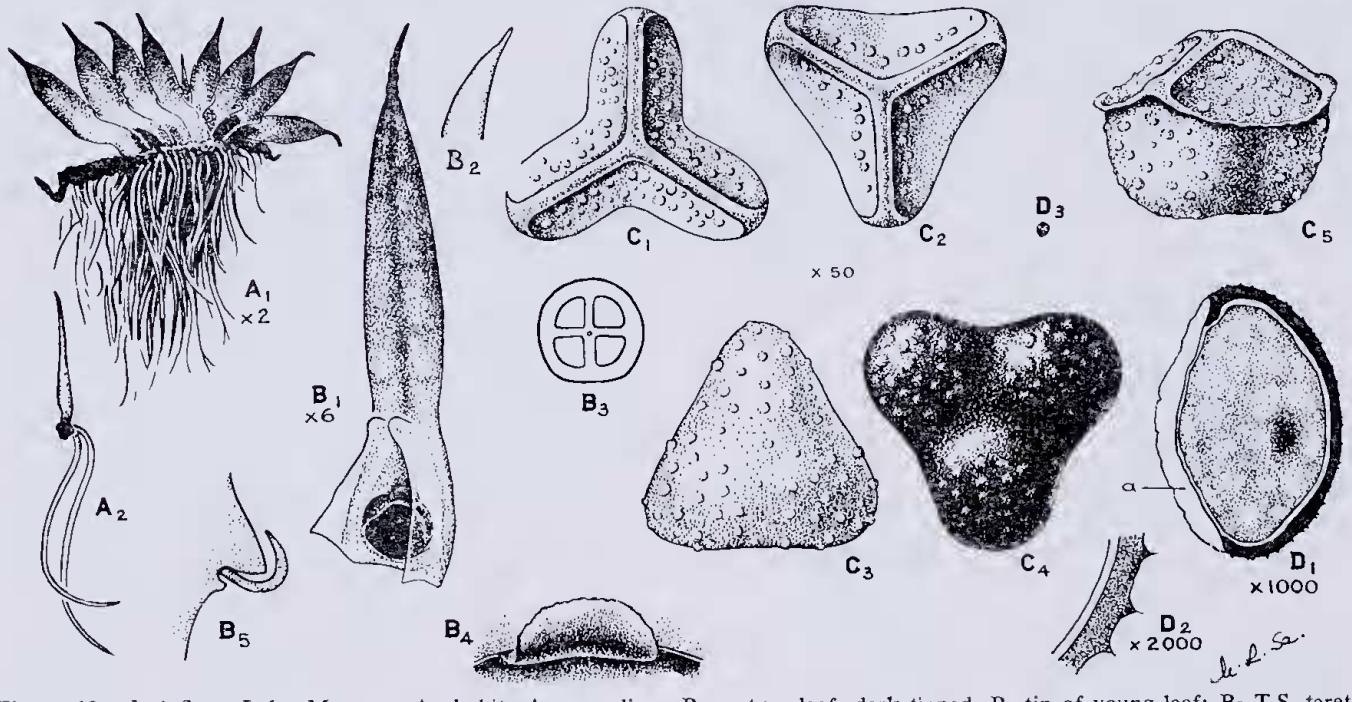

Figure 10.—*I. inflata*, Lake Monger. A_1 habit, A_2 sporeling; B_1 mature leaf, dark tipped, B_2 tip of young leaf; B_3 T.S. terete part of leaf, B_4 reniform ligule, B_5 diagram ligular pit in fovea; C_1-C_4 megaspores showing variation in shape and sculpture, C_4 distal face of mature black trilobate spore, C_5 lateral view megaspore; D_1 microspore, D_2 spinose wall, D_3 microspore x 50.

Distribution (Fig. 11): *I. inflata* occurs in granite rock pools in inland areas in the southwestern part of the Eremaean Province and in an adjacent area of the South-West Province around Pithara.

Specimens examined (selection only): Western Australia: 18 miles northwest of Morawa; 27.vii.1964; *D. Yates* (UWA 720).—Wannarra; 23.viii.1957; *C. A. Gardner* (PERTH, UWA).—8.8 miles from junction of Pithara-Kalannie road and Great Northern Highway; viii.1964; *G. G. Smith* (UWA 378).—17 miles east of Pithara; 23.vii.1971; *N. Marchant* 71/304 (AD, PERTH*).—Granite rock near Coward Homestead about 50 miles northnorthwest of Bullfinch; 11.ix.1964; *S. James & J. Courtney* (UWA 406b).—Elachbutting, east of Muckinbudin; 16.ix.1962; *N. Marchant* (AD, UWA 329).—292 mile peg Great Eastern Highway, near Boondi; 5.ix.1964; *J. Courtney & S. James* (UWA 422).

Note. The epithet (Latin *inflatus* = swollen) refers to the leaves which appear swollen above the wings. The species differs from others in its megaspores being three-lobed.

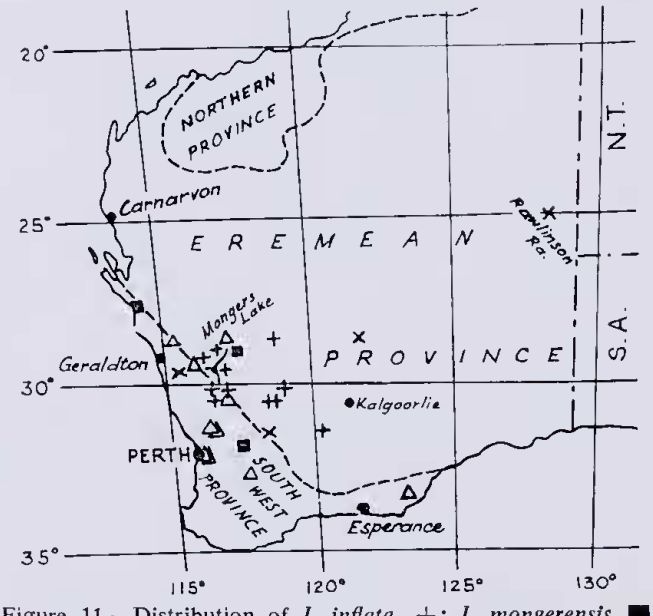

Figure 11.—Distribution of *I. inflata*, +; *I. mongerensis*, ■; *I. muelleri*, ×; *I. tripus*, △.

6. **Isoetes mongerensis** E. R. L. Johnson, sp. nov.— Figs 11 and 12. Caudex trilobus. folia teretia sed parum quandrangularia, 1-1.5 cm longa, attenuata, ad medium 0.8-1 mm diametro, firma, plus minusve divergentia. Megasporae tuberculis numerosis dispersis et cristis paucis plerumque brevibus.— *Typus:* Western Australia. Near Lake Monger [now Mongers Lake], in granite rock pool; August 1958; *C. A. Gardner s.n.* (AD 97134005 holo, PERTH).

Plants small ca 1.5 cm tall (Fig. 11b). *Stock* firm, dark, 3-lobed to 1 cm wide × ca. 0.5 cm deep, abscission caps prominent, upright remains of old leaf bases with a few small dark scale leaves closely investing the broad bases of the narrow spreading leaves. *Leaves* 6-12, 1-1.5 cm long × 0.8-1 mm diam. near mid-point of blade; blade rigid, narrowing abruptly above the concealed broad base, tapering apex acute, T.S. 4-angled; wings firm, short, ca. 4 mm long × 3 mm wide at base narrowing gradually to end a short distance above the ligule on the adaxial leaf surface; ligule variable, short and broad, apex pointed or rounded; labium very small or absent; velum absent or narrow, thin (Fig. 12 B_1a); stomata sparse; peripheral strands absent. *Megasporangia* immature, circular-oval in face view, ca. 1.5-3 mm long × 1.5-2 mm wide; wall firm, hyaline, light yellowish, brown as walls become thickened, not margined; megaspores to 48 per sporagium, dimorphic, ca. 200-300 μm and 350-450 μm, dark (wet), greyish-white (dry); proximal faces tubercles prominent, scattered, irregular in shape, crests few, short, some confluent; distal face crests prominent, scattered, tubercles few; commissural ridges rounded-acute, on small spores slightly sinuous; equatorial ridge thin, acute. *Microsporangia* rare, immature, circular ca. 2 mm diam. similar in structure to megasporangia; microspores cream-brownish in mass, in lateral view ca. 36 μm long × 20 μm deep; wall thick, brownish almost smooth, crest absent.

Distribution (Fig. 11): First collected near Mongers Lake. Later two collections were made from isolated stations in the South-West Province, one in its northern part in the Kalbarri National Park and the other about 600 km south-southwest on Kwolyin Rock.

Further specimens examined: Western Australia: Kalbarri National Park ca. 120 km north of Geraldton; 26.vii.1969; *P. G. Wilson 8316* (PERTH).— Kwolyin Rock ca. 40 km east of Quairading; 12.ix.1979; *N. Marchant 270* (PERTH*).

Observations: Plants grow submerged in rock pools on granite. The largest ones, 2.5 cm tall with stocks about 1 cm, were on Kwolyin Rock in water 10 cm deep and also in the Kalbarri collection. On leaves of different ages, often on the same plant, the ligule varied in shape from triangular to almost reniform. On plants from Kwolyin Rock the velum was present as a thin hyaline membrane and varied in size on the same plant from very narrow to one-half or three-quarters the length of the sporangium. No firm, complete velum, as in *I. muelleri*, was seen. Also on the walls of the immature sporangia were brownish flecks due to groups of cells with slightly thickened walls interspersed with thin-walled ones, a type of structure characteristic of *I. tripus*. As their other characters differ from those of *I. tripus* and are similar to those of the type of *I. mongerensis*, they are referred to this species.

The Mongers Lake plants were homosporous, microsporangiate ones being rare. Those from Kwolyin Rock were megasporangiate, from Kalbarri heterosporous with microspores in an early stage of development. No plants bore mature spores. Old megaspores and sporelings were among the roots of plants from Kwolyin Rock and Kalbarri. Joined and dimorphic megaspores occurred in a single sporangium on a Mongers Lake plant (Fig. 12C_4). This contained 41 spores, 10 joined in pairs by tubes from their proximal faces and 7 had the broken ends of tubes projecting from theirs. Pant and Srivastava (1962) reported spores joined in a similar way in 6 Indian species and stated this type of tubular connection is only known to occur in *Isoetes*.

Plants of this species are distinguished by their narrow, angular spreading leaves, prominent firm 3-lobed stocks bearing the remains of old leaves which closely invest the broad leaf bases.

7. Isoetes muelleri A. Braun, Monatsber. K. Akad. Wiss. Berlin 13 Aug 1868: 528-530, 541 (1868); Luerssen, J. Mus. Godeffroy 3:121 (1875);

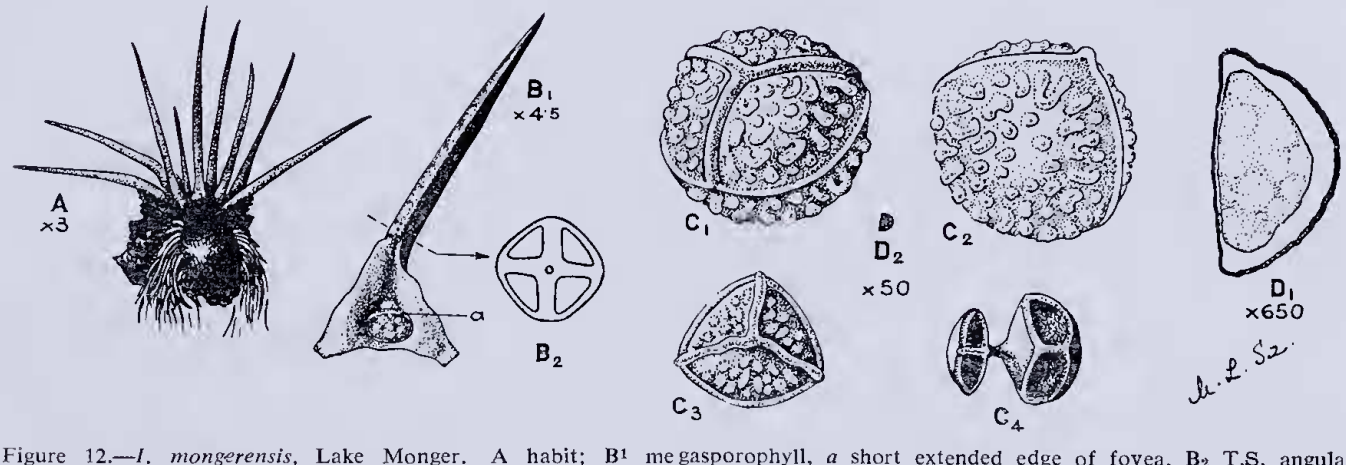

Figure 12.—*I. mongerensis*, Lake Monger. A habit; B^1 megasporophyll, *a* short extended edge of fovea, B_2 T.S. angular blade; C_1C_2 megaspores proximal and distal faces, C_3 small megaspore, commissural ridges sinuous, C_4 joined spores; D_1 microspore, D_2 microspore × 50.

Baker, J. Bot. 18:65, 69 (1880); F. Muell., Syst. Census Austral. Pl. 1:136 (1882); Bailey, Syn. Queensl. Fl. 672 (1883); Mot. & Vendr., Actes Soc. Linn. Bordeaux 36:389 (1882); Baker, Handb. Fern-Allies: 127 (1887); F. Muell., Sec. Syst. Census Austral. Pl. 1:228 (1889); Bailey, Catal. Pl. Queensl.: 58 (1890); Bailey Queensl. Fl. 6:1923 (1902); Sadeb. in Engler & Prantl, Nat. Pflanzenfam. 1/4:777 (1902); Pfeiffer, Ann. Missouri Bot. Gard. 9:127 (1922); Reed, Bol. Soc. Brot. II, 27:41 (1953).—*Calamaria muelleri* (A. Braun) Kuntze, Revis. Gen. Pl. 2:828 (1891).—*Typus:* "Locis humidis ad Rockhampton Australiae orientalis tropicae legit *P. O'Shanesy* 1867 comm. Ferd. Müller." (B holo).—Figs 3, 11 and 13.

[*I. tenuissima* F. Muell. ex A. Braun, Monatsber. K. Akad. Wiss Berlin 13 Aug 1868: 541 (1868) pro syn. (non Boreau, Bull. Soc. Ind. d'Angers 21:269 (1850), n.v.; Mot. & Vendr., Actes Soc. Linn. Bordeaux 36:351 (1882)).]

Plants 3.5-12 cm tall; leaves rather lax and spreading, bases slightly bulbous. *Stock*: small, 3-7 mm wide, firm, 3-lobed, lobes short, abscission caps small, sometimes persistent. *Leaves* 8-25, slender, semi-terete, attenuate, up to 12 cm long × 1 mm broad near middle of blade, ± colourless towards base; wings narrow, thin, narrowing along margins of blade above ligule; ligule 1-2 mm long, ± triangular, base sometimes broad and cordate; labium very short; velum present, firm, pale, usually complete; stomata present; peripheral strands absent. *Megasporangia* circular or oval in face view, ca. 2-3 mm long × ca. 2 mm broad, not margined; wall (mature) brown, epidermal cells with walls yellowish-brown, slightly thickened, lumina large; megaspores dimorphic, ca. 200 μm and ca. 300-450 μm, immature white to greyish-white dry, creamy-dull brown wet, mature darkish-grey dry, dark but not black wet; proximal faces with short and branching crests, few tubercles; distal face crests predominant, sharp, sinuous, branched often confluent; commisural ridges ± low, rounded; equatorial ridge thinner; sculpturing may be absent near ridges; abnormal spores (Fig. 13 C_3C_4) present, in lateral view ca. 500 μm × 350 μm deep, numbers of proximal and distal faces and ridges vary. *Microsporangia* similar in size and shape to megasporangia; wall brown, firm. Microspores immature creamy in mass, fawn-brown as they mature; in lateral view ca. 30-33 μm long × 18-21 μm deep, usually shortly spinose, sometimes almost smooth, crests rare.

Distribution (Fig. 11): A new record for Western Australia. Collections are from four widely separated localities. Two are in the Eremean Province, the furthest inland and most northern near the Northern Territory border at Glen Cuming and the second about 800 km to the south-west near Morgans. A third locality is in the northern part of the South-West Province at Mingenew about 640 km west of Morgans and the fourth, near Merredin, a further 480 km to the south-west near its eastern boundary with the Eremean Province. This discontinuous distribution may be due to the low number of collections made. Though formerly known only from Queensland this species has been found to be widely distributed in Australia. Chippendale (1960) recorded it from Central Australia on Ayer's Rock and specimens have been

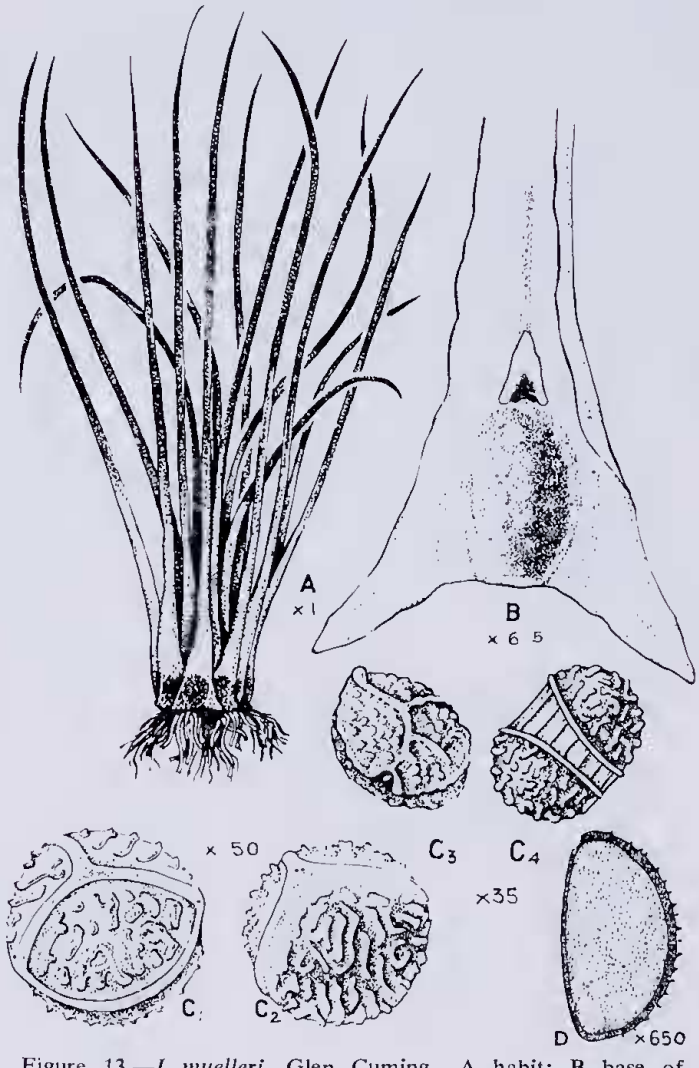

Figure 13.—*I muelleri*, Glen Cuming. A habit; B base of sporophyll with complete velum; C_1C_2 megaspore proximal and distal faces, C_3C_4 two abnormal spores; D microspore.

examined from the Northern Territory (PERTH), southeast South Australia (AD), Victoria (AD, B, M, MEL, MO, P, W) and New South Wales (SYD). No specimens have been seen from Tasmania.

Specimens examined (only W.A. specimens listed): Western Australia: Glen Cuming, Rawlinson Range; 21.vii.1967; *A.S. George 8840* (PERTH).—Glen Cuming, Rawlinson Range; 6.viii.1967; *R. C. Carolin 6128* (SYD).—9.6 km west of Morgans; 29.viii.1962; *A. S. George 4117* (PERTH).—Mingenew; 16.x.1959; *J. C. Knight* (UWA 484).—Durgacutting Rock, ca 6.4 km north of Merredin; 13.ix.1970; *N. Marchant 323* (PERTH*).

Observations: Grows submerged in shallow granite rock pools at Glen Cuming (Fig. 3) and in 30 cm water in sandy soil in a large dam near Merredin. Other habitats were in swampy soil at Mingenew and in red loam near a creek near Morgans. Immature megaspores, but no microspores, were on plants collected in late winter and spring at Glen Cuming, Morgans and Merredin. Mature megaspores were obtained in washings from the old roots. Microsporangia only occurred on some plants from Mingenew and on a few were also small megasporangia with immature spores.

Microspores are described for the first time here as Braun did not find mature microspores on his specimens. The velum, a characteristic feature of this species, is usually complete. It was narrow on the Mingenew plants and on a single plant from Morgans it varied from narrow to up to three-quarters the length of the sporangium.

Dimorphic megaspores were present in all collections and were often found in almost equal numbers in the same sporangium. They also occurred among the roots. They appear to be a characteristic feature of this species as they are present on the type from Rockhampton and specimens from other Australian States. Joined megasports were frequent on the Morgans and Durgacutting Rock plants. Their prox.mal faces were joined by one or more fine tubules which easily broke off and left a scar on the spore wall. Single large almost oblong spores with abnormal development of their proximal faces and ridges occurred (Fig. 13 C_3C_4).

Distinguished from other species by the pale firm velum, the predom.nance of sharp crests on the distal faces of the megaspores, a small trilobed stock and rather lax slender tapering leaves.

8. **Isoetes tripus.** A. Braun, Monatsber.K.Akad.Wiss. Berlin 7 Dec 1863: 559, 566, 567, 573, 574, 582, 591, 593, 594 (1864); 13 Aug 1868; 528-530, 535, 544-545 (1868); Baker, J. Bot. 18:66, 109 (1880); Mot. & Venor., Actes Linn. Soc. Bordeaux 36: 361-362 (1882); Baker, Handb. Fern-Allies: 132(1887); F.Muell., Sec. Syst. Census Austral. Pl. 1:228 (1889); Sadeb. in Engler & Prantl, Nat. Pflanzenfam. 1/4: 778 (1902); Pfeiffer, Ann. Missouri Bot. Gard. 9: 176 (1922); Reed, Bol.Soc.Brot., II,27:50 (1953).—*Calamaria tripus* (A. Braun) Kuntze. Revis. Gen.Pl.2:828 (1891).—*Typus*: ". . . in herb. Vindob. et Hook. 1863. Ad flumen Swan River detexit *Drummond 1843 (no. 990).*" Nouvelle Hollande occidentale R. des cygnes; c1844; *Drummond 990.* (W lecto, AD photo; B, K, P). (See note on lectotypification below.)—Figs. 11 and 14.

I. phaeospora Durieu, Bull.Soc.Bot.France 11: 103 (1864); F. Muell., Fragm. 5: 140(1866); Reed, Bol.Soc.Brot.II,27: 44(1953).—Typus: ". . . . *Drummond* dans la Nouvelle-Hollande, en 1842 et 1843 . . . L'étiquette de Drummond porte pour toute indication de localité: "Swan River." " (P n. v., herb. Delessert n.v.) (See note on lectotypification below.)

Plants (Fig. 14) to 7 cm tall, leaves slender forming a tuft invested at base parts of stock. *Stock* 3-lobed, dark, firm, abscission on caps persistent, projecting horizontally or slightly upwards, sometimes horny. *Leaves* up to 11, 4-7 cm long, some shorter, ca. 0.5-1 mm broad, semi-terete, attenuate, apex often obtuse, green except near base; wings slightly fleshy, long, gradually narrowing above the level of the ligule; ligule often triangular, apex acute or obtuse, base cordate, sometimes short almost reniform; labium short; velum absent, edge of fovea sometimes acute, extending shortly over sporangium; stomata numerous; peripheral strands absent; median horizontal grooves on the lower dorsal surface of mature leaves. *Megasporangia* almost circular or oval, 2 mm long × 1.5-2 mm broad, or 3.5-6 mm long × 1.5-3 mm broad, mature flat adaxially, margin slight, wall with small dark brown flecks rarely dark brown allover; megaspores immature 350-500 μm, immature wet dark, dry whitish, mature dry dull brown; proximal faces few tubercles, crests numerous, short, long, branched, distal face crests numerous, rather sharp, branched, often confluent forming few or many reticulations, commissural ridges low ± rounded, equatorial ridge thin. *Microsporangia* similar in size, shape and

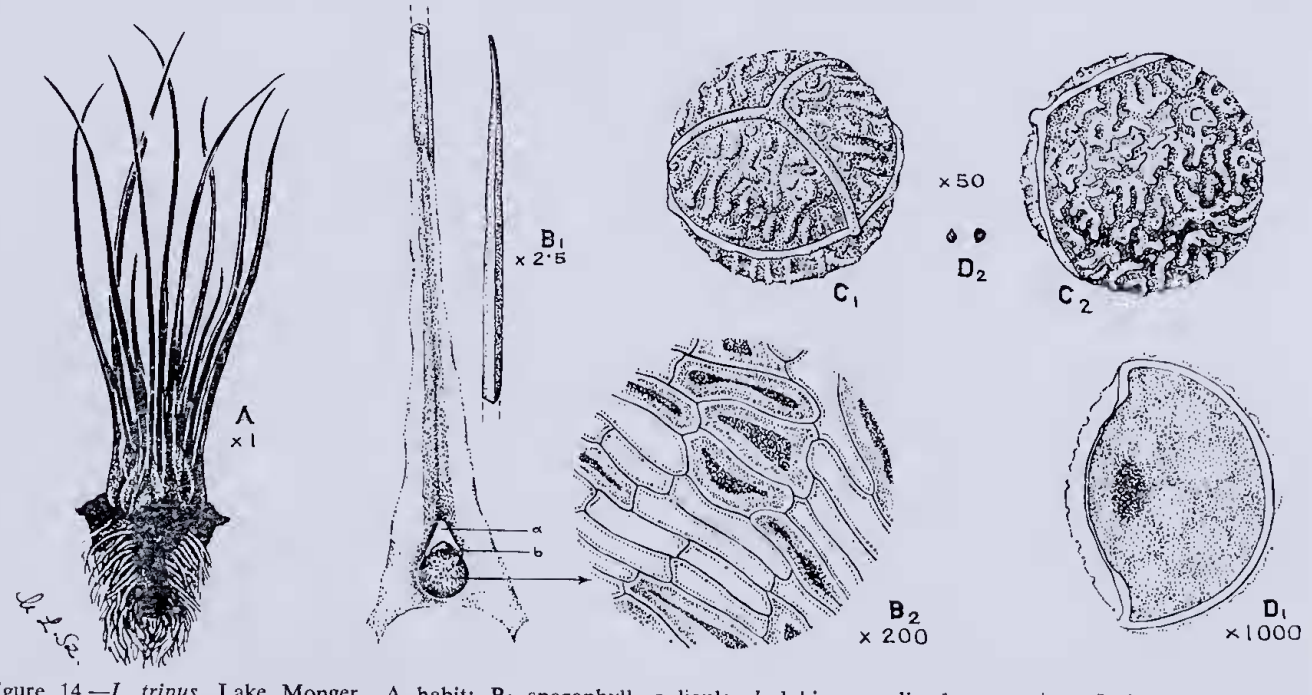

Figure 14.—*I. tripus*, Lake Monger. A habit; B_1 sporophyll, *a* ligule, *b* labium, wall of sporangium flecked, B_2 thick and thin walled cells of sporangial wall; C_1C_2 megaspores proximal and distal faces; D_1 microspore with crest and thin envelope, D_2 microspore × 50.

structure to megasporangia; microspores immature fawn in mass, mature dark brown, in lateral view 30-36 μm long × 18-24 μm deep, wall smooth or almost so with outer thin hyaline envelope, crest present variable in depth.

Distribution (Fig. 11): *I. tripus* is endemic to Western Australia where it occurs mainly in the South Western Province north of lat. 33°S and in the Eremean Province near Mongers Lake. A single collection, considered to be a form of *I. tripus*, was made at Pine Hill an isolated locality east of Esperance. The location at the Swan River where Drummond collected the type is not known.

Specimens examined (selection only): Western Australia: 270 mile peg Mullewa-Morawa road; August 1964; *G. G. Smith* (UWA 376).—Petrudor Rock, east of Pithara; 23.v.i.1971; *N. Marchant* 71/310 (PERTH*).—Toodyay road, between Toodyay and Clackline; October 1964; *G. G. Smith* (UWA 454).—Mundaring-Beraking road; 17.ix.1962; *G. G. Smith* (UWA 331).—11 km north of Tinkurrin; 10.xi.1960; *G. G. Smith* (UWA 482).—Pine Hill, 57.6 km north-west of Israelite Bay; 15.ix.1971; *N. Marchant 71/437* (PERTH*).

Observations: Plants are usually on or near granite outcrops, in shallow rock pools, in adjacent soakage areas with shallow soil or in moss sward on granite. Plants are not submerged and grow and perennate under similar conditions to those described for *I. drummondii*.

In most collections plants were immature. Megaspores were whitish and mature ones, obtained from among the old roots, were dull brown.

Variations occurred in the shape of the ligule, the number and size of the flecks on the sporangial walls and the development of reticulate sculpturing on the megaspores. Ligules were short ± triangular on the Swan River plants. On some from Mongers Lake and Toodyay (UWA 454) the base was broad and cordate and apex obtuse, on others it was almost reniform. The sporangial wall appeared uniformly brown, and not flecked, in collections from Toodyay (UWA 454), Pine Hill (PERTH) and Goebel's specimen from Perth (M). Complete reticulate sculpturing of the distal faces of the megaspores was rare. Plants were heterosporous. Some plants in a collection made in November at the end of the growing season near Tinkurrin bore only megasporangia.

Plants of this species can be recognized by their fine leaves, firm 3-lobed stock with prominent often horny and slightly upturned abscission caps, dark brown flecks on the sporangial walls and dull brown mature megaspores.

Note on lectotypification: No type was indicated by A. Braun in the first valid publication (1864) of *Isoetes tripus*. In his second paper (1868) he lists "Ad flumen Swan River detexit Drummond 1843 (No. 990)" and the location as "herb. Vindob.et Hook." (= W and K). I have seen both these specimens and designate the W sheet as lectotype and the collection on the K sheet as isolectotype. Both collections are annotated by A. Braun and of equal quality. The W sheet bears *I. tripus* (Drummond 990) only, while on the K sheet is mounted also a collection of *I. drummondii*. Further isolectotypes I saw from P, W and B. A. Braun annoted the B sheet "*Isoetes tripus* Mihi" and on its label is "Swan River Drummond 1843 No. 990". It bore five packets, three labelled *I. tripus* and two *I. drummondii*, each in A. Braun's handwriting. Collections on the other sheet from W and that from P were not annotated by Braun. The W sheet had "Swan River Drummond 990" on it without date and the P sheet "Nouvelle Hollande occidentale R. des cygnes (Swan River) Drummond 1843" without number. On a second P sheet bearing two plants under Drummond's 989—*I. drummondii*, the right-hand one was found to be *I. tripus*.

I have not seen a specimen collected by Drummond from "Swan River" which was annotated by Durieu as *I. phaeospora*, but it can be safely assumed that it belongs to *Drummond No. 990*, the type collection of *I. tripus*, as this is the only one collected by Drummnod with brown megaspores, a feature described by Durieu as diagnostic for his species. As *I. tripus* was almost certainly published early in 1864 and *I phaeospora* later in the same year, and both names are based on the same collection, I have no hesitation to follow A. Braun in placing the latter as a synonym under *I. tripus*.

Typification of names of Australian *Isoetes* species not known to occur in Western Australia

In the course of this revision of Western Australian species of *Isoetes* a knowledge of the other species of the genus known to occur in Australia had to be gained and the application of their names examined. As no definite holotypes were published, it was indicated to designate lectotypes where appropriate for the names listed below, which were selected from specimens examined, and to publish these here as follows:

I. elatior F. Muell.ex A. Braun, Linnaea 25:722 (1853); Monatsber.K.Akad.Wiss. Berlin 13 Aug 1868:536.—*Typus:* "In Tasmania legit *Stuart*." (A. Braun 1853); "*I. elatior* Ferd.Müll.in herb. Sonder ... In fluvio South Esk River Tasmaniae 1. *Stuart 1849 (No. 461)* ..." (A. Braun 1868). From the protologue with the emendation of 1868 it is reasonable to designate the relevant specimen at MEL (sheet No. 1002781) as lectotype of *I. elatior*; the duplicate material at B is to be regarded as an isolectotype.

I. gunnii A. Braun, Monatsber.K.Akad.Wiss. Berlin 13 Aug 1868:535 (1868).—*Typus:* "*I. Gunnii* A.Br.in herb.Hook. 1866 ... In lacubus montanis Tasmaniae, fundum longe lateque obducens. *R. Gunn 1841 (No. 1563)* ... Die ... Exemplare sind aus dem Lake St Clair." From this protologue it is evident that the relevant specimen at K (herb. Hooker) is to be regarded as the holotype of *I. gunnii*.

I. hookeri A. Braun, Monatsber.K.Akad.Wiss. Berlin 13 Aug 1868:538 (1868), *nom. illeg.*—Because *I. humilior* F. Muell. ex A. Braun (1853) is quoted as a synonym and its type not excluded, and it thus is the type of both names, *I. hookeri* A. Braun is illegitimate. For typification see under *I. humilior*.

I. humilior F. Muell. ex A. Braun, Linnaea 25:722(1853).—*Typus:* "In fluvio South Esk River Tasmaniae, Aprili 1849, legit *Stuart*." A. Braun

(1868) changed the name for this speices to *I. hookeri* stating that F. Mueller included (in sched.) two species under the name *I. humilior* (v.z. *I. hookeri* and *I. stuartii)*. A. Braun then quoted for *I. hookeri,* to which he referred *I. humilior* as a synonym, *"I. Hookeri.* A.Br. in herb.Melbourn. 1866 . . . . *Stuart 1849 (no. 579)".* From this emended protologue it is reasonable to designate MEL 1002782 as the lectotype of *I. humilior.* It is automatically the lectotype of the illegitimate name *I. hookeri* although this name does not appear in A. Braun's handwriting on the MEL sheet. A. Braun annotated a fragment of the same collection in B with the name I. hookeri.

I. stuartii A. Braun, Monatsber.K.Akad.Wiss. Berlin 13 Aug 1868:539(1868).—*Typus: "I. Stuarti.* A.Br. in herb.Melbourn. 1866 . . . . In fluvio South Esk River Tasmaniae inter pracedentes [*I. elatior* and *I.* hookeri ≡ *I. humilior*] l. *Stuart."* A. Braun (1868) says that he has seen only one specimen of this species which belongs to the Melbourne Herbarium. Accordingly the relevant sheet at MEL (no. 1002783) must be regarded as the holotype of *I. stuartii* A. Braun; an isotype is in B.

I. tasmanica F. Muell. ex Durieu, Bull.Soc.bot. France 11:104(1864), *nom. illeg.*—Durieu (1864) had examined specimens from Tasmania collected by W. Archer and R. Gunn and concluded that *"Is. elatior* et *humilior* sont spécifiquement identiques". He united the two species described by A. Braun (1853) under the name *I. tasmanica* which he attributed to F. Mueller. Therefore, the name is illegitimate under the International Code of Botanical Nomenclature and a lectotypification is unnecessary.

Acknowledgments.—The author is grateful to Dr Hj.Eichler, Keeper, State Herbarium of South Australia (AD), and his staff for providing working space and facilities, including the arrangements for loans from other institutions, to carry out this study in her retirement from the Department of Botany, University of Western Australia. She is particularly grateful for stimulating and encouraging discussions during the course of this work and valuable advice on typification and other nomenclatural matters. To the following institutions she is indebted for the loan of specimens including types: AD, ADW, B, CHR, K, M, MEL, MO, NY, OXF, P, PERTH, SYD, US, UWA, W and WELT. Special thanks are due to Alex S. George (PERTH), Kevin F. Kenneally (UWA) and Gordon G. Smith (UWA) for their efforts to collect fresh material and specimens preserved in formalin or FAA. Mrs M. L. Szent-Ivany illustrated this paper with line drawings and maps; her contribution is thankfully acknowledged. Photographs of habitats were provided by A. S. George and K. F. Kenneally. Gratitude is expressed to the CSIRO Science and Industry Endowment Fund for providing a stereomicroscope and financial support mainly towards the illustrations.

Editorial Note.—The largest part of the manuscript had been written up by hand by Mrs Johnson when she died on 11 August 1972, including the abstract, introduction, keys to the species, texts to most of the species, and the bibliographic references. Those parts missing (i.e. on *Isoetes caroli, I. inflata,* the Latin diagnoses of the new species, and the note on typification of the names of some other Australian species) were compiled by Hj.Eichler from the description of individual specimens Mrs Johnson left in her card index and other scattered handwritten notes. He attempted to conform with the style of presentation used by Mrs Johnson in the parts of the manuscript she had completed and prepared the paper for publication.

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